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SAN DIEGO BAY

AN EVALUATION OF THE BENTHIC ENVIRONMENT

OCTOBER 1967

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
CINCINNATI, OHIO

1968

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16. Abstracts The results of a biological survey of the San Diego Bay, California, to assess the effects of pollution from ships and industries on the bay's biota are presented. The survey included studies of the distribution and diversity of invertebrate organisms in or on the bottom and the depth and composition of the benthic sediments in the bay. A Peterson dredge collected bottom-associated organisms, core samples determined the extent and condition of sludge deposits, multiplate substrates collected attached benthic forms, and two SCUBA divers observed selected areas of the bay and collected representative organisms.

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SAN DIEGO BAY. AN EVALUATION OF THE BENTHIC ENVIRONMENT

OCTOBER 1967

by

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1968

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SUMMARY AND CONCLUSIONS

(1) San Diego Bay has a surface area of approximately 18.5 square miles. The bay is surrounded by metropolitan San Diego, and most of the shore line has been developed for recreational, residential, military or industrial use. There is no dilution of San Diego Bay by freshwater in the summer and salinities range from 33 to 34 ppt (parts per thousand) over most of the year. A decreased amount of wastewater enters the bay since the completion of an off-shore ocean outfall in 1963. Prior to 1963, all municipal and industrial wastes were discharged to the bay.

(2) Pollution to the bay results principally from a tuna cannery, a kelp processing plant, naval vessels and a storm drain from the San Diego Zoo. Off-shore from these waste sources, rapidly decomposing sludge deposits restricted the number of

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kinds of bottom-associated organisms to three or less.

Less than five kinds of organisms or more than 200 polychaete worms per square foot are considered to be indicative of polluted conditions in San Diego Bay.

(3) The naval pier area in Central Bay contained sludge ranging from 14 to 44 inches in depth. Bottom organisms were predominantly polychaete worms, an indication of moderate to severe organic pollution. Pollution tolerant snails, scuds and shrimp were present where the sludge was partially stabilized. In some areas, actively decomposing sludge with high organic carbon values, ranging from 3.8 to 4.5 percent, covered old decayed sludge that probably was deposited by the city of San Diego before 1963, indicating a continuing contribution to sludge beds from naval ships docked in the area.

(4) The channel off-shore from the naval piers was covered by 33 inches of older and more stable sludge that supported over 1300 polychaetes per square foot. Sludge from the naval areas apparently was being resuspended, transported by currents and redeposited in the channel thus producing an organically enriched channel bottom.

(5) In the entrance, Gloriette Bay contained a thin covering of sludge that supported only 22 polychaete worms per square foot and one other kind of organism, an indication of moderate to severe pollution. Farther inside the bay, the bottom area sampled contained no sludge but was slightly polluted with organic material that supported 462 polychaetes per square foot, plus only three other kinds of organisms.

(6) Sludge and oils covered the bottom northwest of the 10th Avenue Marine Terminal.

The combination of sludge and oil was toxic to most benthic organisms and inhibited the decomposition of the sludge.

(7) South Bay was polluted in two areas: (a) The heated cooling-water effluent from a steam electric plant caused an increased growth and die-off of microscopic organisms that settled to form deposits of organic material. Over 1400 polychaetes per square foot and one species of pollution tolerant snail existed in the effluent channel. (b) Algae were matted over 10,000 square feet of bottom off-shore from the Rohr Aircraft Co., indicating the discharge of nutrients into the area. This algal mat is a potential nuisance. The die-off, decay and resulting odor problems could restrict additional property development and beach utilization in the area.

Seven to eleven kinds of organisms existed in this polluted environment.

(8) North Bay was polluted by a storm drain from the San Diego Zoo which discharged wastes in the vicinity of the B Street pier. Benthic organisms were predominantly polychaetes; sludge covered approximately 40,000 square feet of the bottom and prevented colonization by food organisms of sport fishes.

(9) The Carrier Basin contained approximately 38 inches of stable sludge supporting both polychaetes and molluscs. Settleable solids from carriers moored in the basin probably contributed to this sludge bed.

(10) Harbor Island Bay contained organic debris that supported over 6,000 polychaetes per square foot, a result of moderate organic pollution. Enrichment was due to dredging of sand from the bay.

The sand is removed, but the light organic materials are washed back to the area thus effecting a concentration of organic materials.

(11) The Commercial Basin and Shelter Island Harbor contain debris and old stable sludge. There are vessels within both areas that could discharge settleable solids to the water. Also, settleable materials transported into the bay by inflowing waters would tend to deposit in these areas.

(12) Excepting the submarine base which was not sampled, the remainder of North Bay contains pollution-sensitive organisms that reflect the unpolluted conditions existing at the harbor entrance.

(13) Preventing the discharge of settleable organic wastes into San Diego Bay would prevent sludge bed formation and improve bottom conditions by allowing more rapid

decay of present sludge beds, thus providing an improved habitat conducive to the growth of food organisms for desirable sport fishes. Water quality would be improved, providing an environment more conducive to boating, water skiing, swimming and aesthetic enjoyment of the bay.

(14) San Diego Bay has improved in condition since the construction of an ocean outfall in 1963. Water quality in the bay can be improved further by the prevention of waste discharges to the bay from the sources listed above.

INTRODUCTION

San Diego Bay, a crescent shaped natural water body, has a length of approximately 15 miles, a maximum width of two and one-half miles and a surface area of about 18.5 square miles. Water depths vary from less than one foot in the southern end to 41 feet in the harbor entrance. The bay is surrounded by metropolitan San Diego with a population of over 860,000. The shoreline area, with the exception of a few small sections, has been developed for residential, recreational, military or industrial uses. A deep-water harbor and extensive docking facilities permit use of the bay for naval activities, maritime commerce, industrial use, research, aesthetic enjoyment and recreation. Varied forms of recreation enjoyed on or in the bay waters are: boating, fishing, swimming, water skiing, and wading.

There is no dilution of San Diego Bay by freshwater in the summer and salinities range from 33 to 34 parts per thousand (ppt) over the entire year except in the south end of the bay where evaporation may increase salinities to 35(+) ppt in the summer. Average water temperature varies from a high of about 26° C during late summer to a low of 14-16° C during the winter.

Prior to 1963, municipal and industrial wastes from the metropolitan areas were discharged into the bay. Since the completion of an off-shore ocean outfall, a minimum amount of wastes now enter the bay.

This biological survey was requested by the Southwest Region, San Diego Bay Study, Federal Water Pollution Control Administration, U. S. Department of the Interior. The objective of the survey was to assess the effects of pollution from ships and industries on the biota of San Diego Bay. The period of study was October 8 to 28, 1967.

WATER QUALITY

The effects of pollution on water quality are indicated by biological populations and the chemical composition of bottom sediments and water. This survey included studies of the distribution and diversity of invertebrate organisms present in or on the bottom, and depth and chemical composition of the benthic sediments in the bay.

Study of the aquatic organisms in a body of water can reveal changes in the environment brought about by the activities of man. Bottom associated or benthic organisms best reflect these changes because they have life spans of one year or more and, because of limited locomotion, they are restricted to local areas. Thus, they reflect past and present water quality at a specific sampling point. In an unpolluted environment, bottom-associated organisms are usually represented by many kinds of organisms with few individuals representing each kind. Introduction of organic substances into the water usually reduces the number of kinds and increases the number of individual organisms; however, severe pollution by organic substances effects a reduction of both numbers and kinds of organisms because of the production of toxic decomposition by-products such as hydrogen sulfide.

Bottom-associated organisms are an important link in the food chain of a water body. In an unpolluted bay a healthy benthic population results in the production of shellfishes and fin-fishes of value to both sports and commercial fisheries. Pollution restricts benthic populations and effects a reduction of higher aquatic organisms of interest and value to man. Water contact sports are also restricted by the pollution of a body of water. Turbid water, floating materials and sludge-like bottoms are aesthetically revolting.

The chemical composition of benthic deposits gives an indication of the effect of such deposits on water quality and associated biota. Deposits rich in organic carbon and nitrogen exert a high oxygen demand as they decompose. When undergoing anaerobic decomposition, they release hydrogen sulfide and methane gas into the water, thus producing a condition toxic to the biota because of a lack of oxygen and the presence of sulfide. Such deposits are nutrient reservoirs that supply nutrients to a body of water until the deposits are finally decayed or covered.

Investigative Methods

To aid data presentation, San Diego Bay has been divided into three sections: South Bay, Central Bay and North Bay (Figure 1).

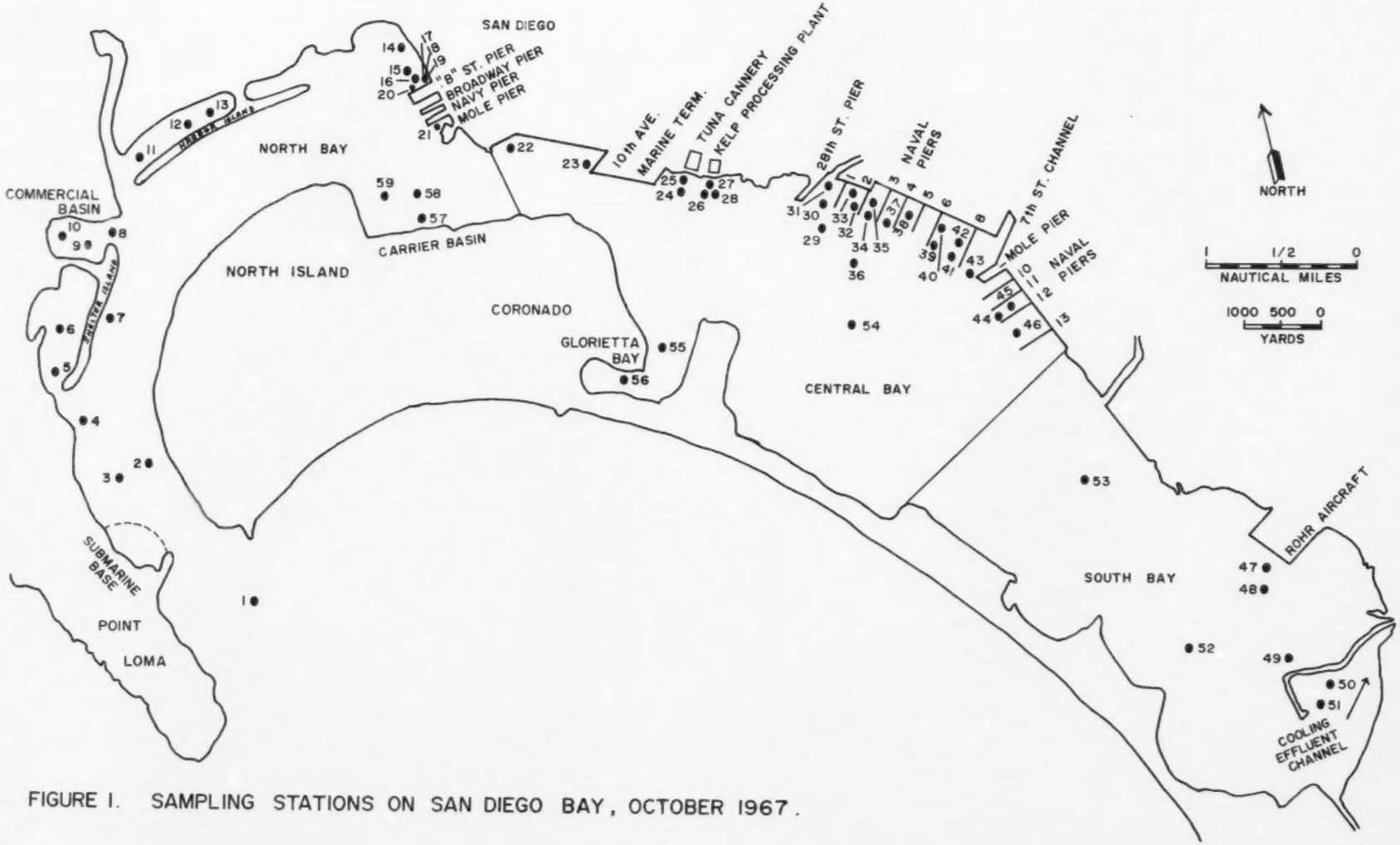

FIGURE 1. SAMPLING STATIONS ON SAN DIEGO BAY, OCTOBER 1967.

South Bay consists of the area south of the reserve fleet, naval piers 10-13; Central Bay includes that portion from the reserve fleet to the ferry crossing; North Bay contains the remainder of the bay from the ferry crossing to the channel entrance.

A Petersen dredge was used to collect bottom-associated organisms. After a bottom sample was collected with the dredge, it was placed in a small tub. Water was added and the sample was mixed to a slurry and strained through a U. S. Standard No. 30 mesh sieve. The organisms and coarse debris were removed from the sieve and preserved for later examination in the laboratory. Results are presented in Tables 1 and 2, and Figure 2.

To determine the extent and condition of sludge deposits in San Diego Bay, core samples were collected with a Phleger type coring device. Sections of each core were placed in labeled containers and returned to Cincinnati for chemical analyses. Sludge depths were determined by measuring the depth or length of penetration of the coring device, evident as a smear of sludge or mud on the outside of the device, and the length of core

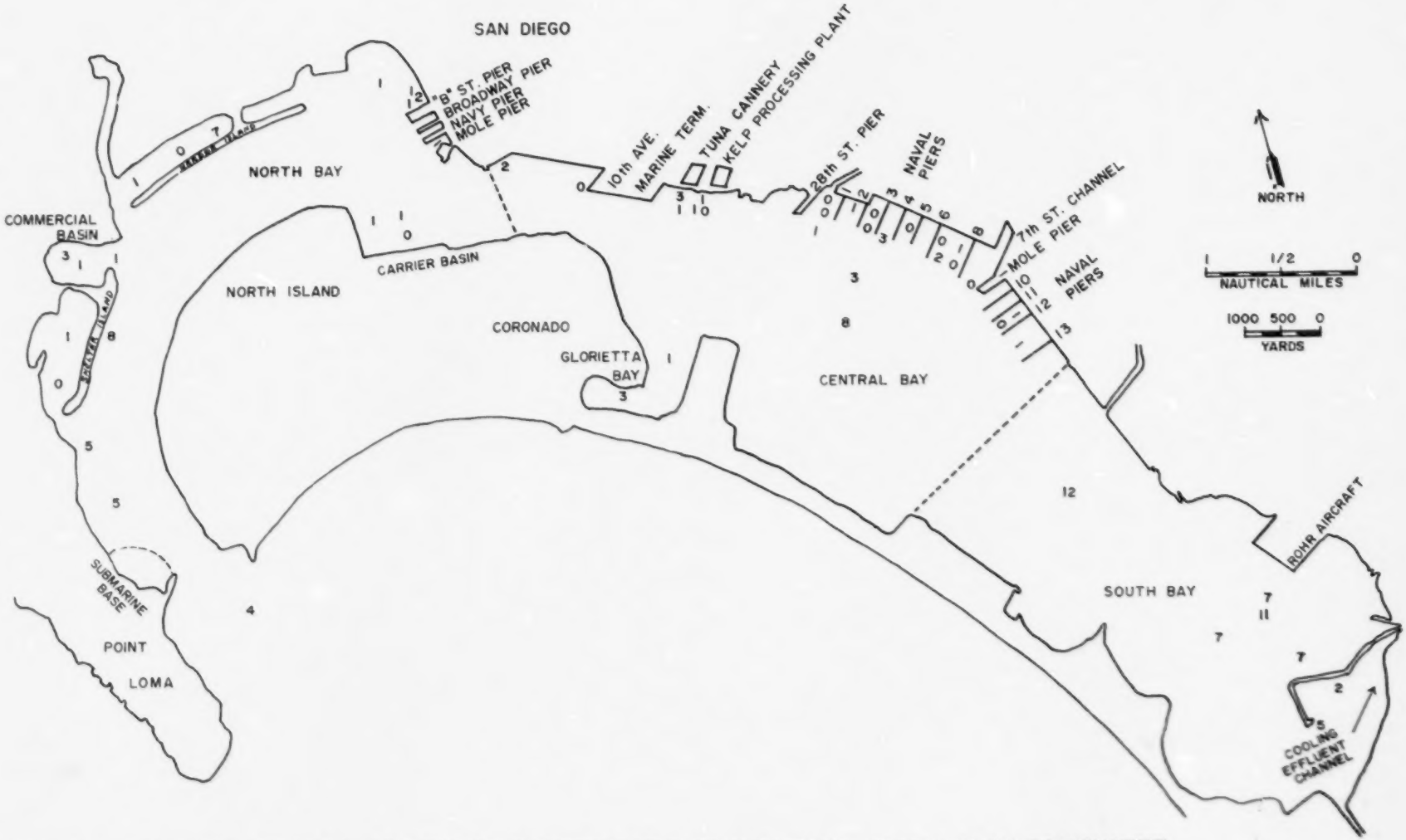

FIGURE 2. NUMBERS OF KINDS OF BENTHIC ORGANISMS PER SQUARE FOOT, OTHER THAN POLYCHAETE WORMS, SAN DIEGO BAY. OCTOBER, 1967.

collected. Core length was divided into the length of penetration to obtain a multiplication factor for the amount of compaction. This factor multiplied by the length of sludge-like material in the core equalled the approximate depth of the sludge samples.

Multiplate artificial substrates, constructed of tempered hardboard, were used to collect attached benthic forms. The substrates were placed in the water for 14 days. After the 14th day, the substrates were collected and attached organisms were scraped off and washed into a small tub. Water and organisms were strained through a U. S. Standard No. 30 mesh sieve and material remaining on the sieve was preserved with five percent formalin.

Two SCUBA divers, trained in aquatic biology, were contracted by the project to observe selected areas of the bay and to collect representative organisms. Data collected by the divers was presented in a report to the project and portions of their findings are included in this report.

South Bay

The south section of San Diego Bay was affected only slightly by pollution. In six of the eight areas sampled,

there were at least seven species of organisms and as many as 13 species in the sandy bottom at station 53 (Table 2). Analysis of benthic data from San Diego Bay indicates that an area with less than five kinds of organisms or more than 200 polychaete worms per square foot represents a polluted situation. The most evident pollution was in the effluent channel from a steam electric plant where the rocky bottom was covered with black sludge and filamentous algae (station 50). A water temperature of 88° F was recorded here at the time of sampling. Floating mats of dead algae were evident and material from the bottom had a distinct hydrogen sulfide or rotten egg odor. Polychaete worms numbered 1408 per square foot, denoting a polluted area; only two kinds of other organisms were found in this channel, a pollution-tolerant snail being the more numerous. The channel held 25 inches of organic sludge containing 2.3 percent organic carbon and 0.16 percent organic nitrogen (Table 3, Figure 3). A value of 2.3 percent organic carbon is indicative of organic debris. These sludges developed because of the rapid growth, die-off and deposition of plants and animals in the heated effluent, as well as

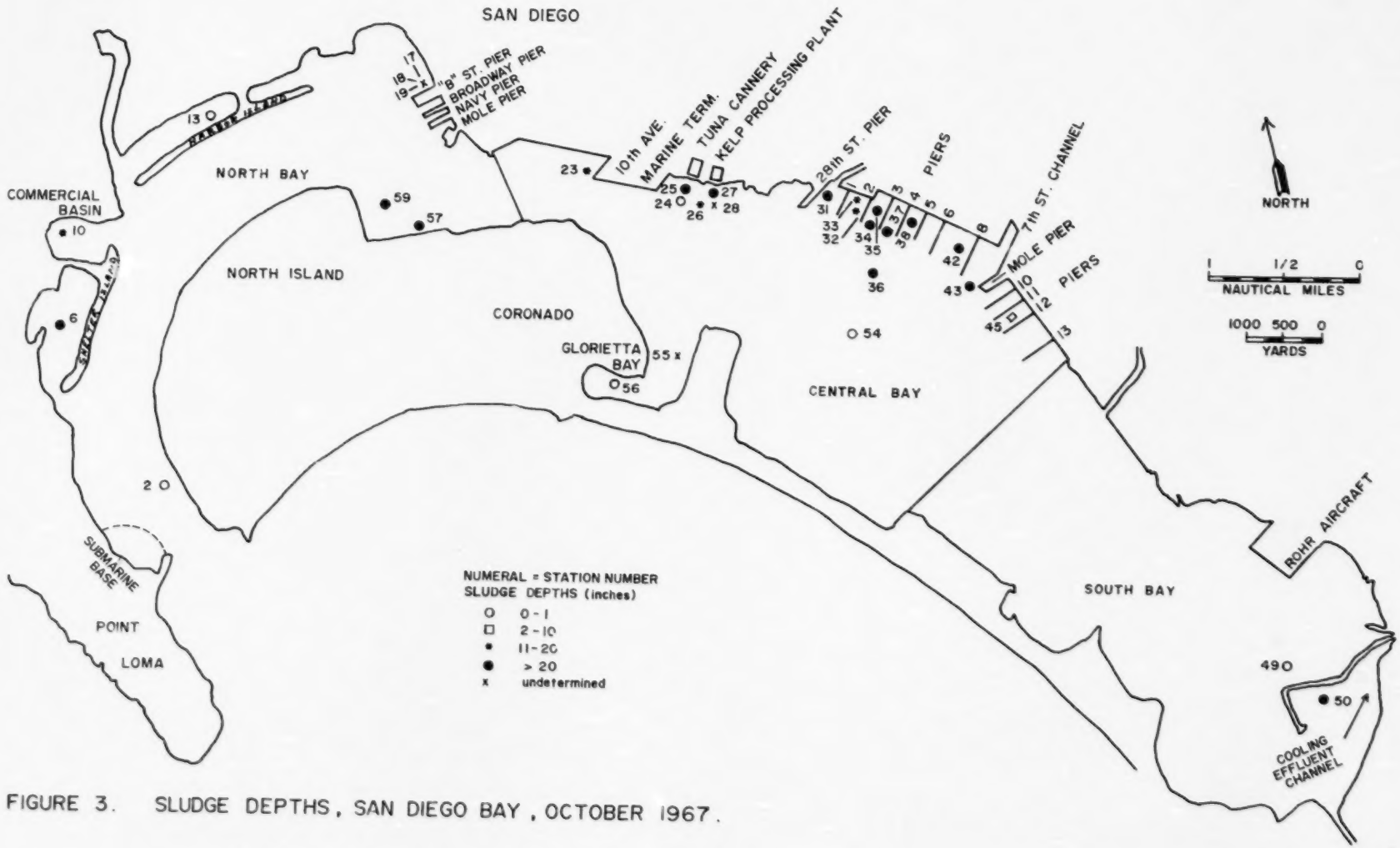

FIGURE 3. SLUDGE DEPTHS, SAN DIEGO BAY, OCTOBER 1967.

the high temperature adaptation of only a few organism types that consume or digest the organic materials.

In contrast, on the other side of a jetty separating the effluent channel from the bay (station 49), 118 polychaetes per square foot and seven kinds of other organisms indicated a cooler and unpolluted environment (Table 2 and Figure 2). A gray mud and sand mixture contained 1.6 percent organic carbon and 0.16 percent organic nitrogen. A sample of clay, sand or loam soils would have 0.4 to 2.1 percent organic carbon and 0.02 to 0.10 percent organic nitrogen.

Off shore from Rohr Aircraft, stations 47 and 48, polychaete populations numbered as high as 498 organisms per square foot (Table 2). The most prominent feature of this area was a bed of algae extending from shore to a depth of ten feet and covering approximately 10,000 square feet. This luxuriant growth, coupled with the number of polychaetes in the area, indicates an area of moderate pollution. Such an extensive algal mat represents a potential nuisance to future shoreline development. Odors resulting from the die-off and

decay of algae are similar to those from rotting sewage and are not conducive to the development of an area for recreational, residential or industrial uses.

Other than the two areas mentioned, South Bay had a variety of organisms, polychaete worm populations as high as 829 per square foot, and a sand and clay bottom. Artificial substrates placed near stations 52 and 53 collected 4 kinds of organisms numbering 1032 per square foot. Two SCUBA divers who surveyed parts of South Bay noted that the area appeared relatively unpolluted and highly enriched, typical of environments where water circulation is minimal and natural build-up of nutrients occurs.

Central Bay

Central Bay was the most polluted section of San Diego Bay. The most kinds of bottom-associated organisms in Central Bay were nine at Station 54 which was only slightly affected by pollution. In the area of the reserve fleet (stations 44 through 46), benthic populations contained as many as 309 polychaetes per square foot with only 1 kind of other organism (Table 2). A two-inch layer of decomposing sludge

with organic carbon and nitrogen values of 4.1 percent and 0.36 percent covered the bottom. The reduced variety of organisms and the presence of decomposing sludge are typical of areas polluted by organic materials.

Bottom-associated organisms collected from between the 28th Street pier and the Mole pier near the 7th Street channel (stations 29 through 43) were predominantly polychaetes (Table 2 and Figure 2). Between piers one and two, the bottom supported 827 polychaete worms per square foot denoting a moderate, but not severe enrichment. In this area (stations 32 and 33), organic carbon values of 3.8 to 4.5 percent in the top layers indicated a possible recent addition of settleable solids, a portion of which was contributed by the discharge of wastes from moored naval vessels. Inside the pierhead line, of piers 2 through 8, the benthic population was restricted to a few polychaetes only, with the exception of station 42; indicating severely polluted conditions. Midway between the ends of the piers and shore (stations 35 and 38), the top layer of the sludge samples had organic carbon contents of 3.8 and 3.3%; these contents are typical of decaying deposits. At the pierhead line (stations 37 and 39), two to three kinds of organisms were able to exist in addition to polychaetes

indicating moderate but not severe pollution. Severe organic pollution results in very low numbers of polychaetes and no other kinds of organisms, such as represented at station 43 with 19 polychaetes per square foot and no other organisms. The bottom at this station had a decomposing sludge layer with organic carbon and nitrogen values of 5.6 and 0.38 percent respectively. Core samples taken at the pierhead line (stations 34 and 37) contained a top layer of sludge with organic carbon values ranging from 2.5 to 2.8 percent and organic nitrogen values of 0.17 to 0.18 percent indicating a more stable sludge.

Gradation from active sludge inshore to a more stable sludge in the pierhead area was substantiated by divers who swam along a transect of the area. The divers described the bottom as soft-muddy silt with a dark black sludge layer under the piers. Sludge was not as apparent to the divers near the pierhead line compared to midway between shore and the pierhead. A variety of fish in the area and a qualitative sample of nine kinds of organisms taken about five feet from the bottom on a piling at the end of pier four indicated that the quality of water overlying the bottom in the vicinity of the pierhead line was not severely degraded. Settleable organic solids are the most significant pollutants in this area.

At station 42, 1 pollution tolerant snail and 11 polychaetes per square foot were able to exist. The bottom was covered with 33 inches of sludge containing 2.2 percent organic carbon and 0.14 percent organic nitrogen. These values indicate a decayed sludge.

Chemical analysis of core samples from stations 34, 35, 37 and 38 revealed a layering of sludge. These areas had 8 to 17 inches of sludge capable of undergoing further decay overlying 6 to 18 inches of sludge with organic carbon values of 5.2 to 9.9 percent and capable of active decay (Table 3). This situation was the reverse of the usual sludge bed where actively decaying sludge covered decayed sludge. Before 1963, the city of San Diego discharged sewage into the area of the naval piers with the resultant build-up of an extensive sludge bed. Since 1963, the city has discharged to an ocean outfall and the sludge beds in the bay have been receding.[1] If these sludge beds were deposited rapidly, thus preventing aerobic decomposition of carbonaceous materials, they may contain large amounts of decaying matter underneath a top layer of decayed sludge. Also currents caused by the movement of naval vessels in the area

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[1]Anon. Report on Water Quality Control Policy. The Resources Agency, State of California, 1966.

may be continually removing the old decayed sludge in some areas and redepositing it over actively decaying layers. Organic carbon values for the top layers of sludge should be below 2.0 percent, representative of old or well decayed sludge, if no additional sludge has been added since the city stopped discharge and if decaying sludge has not been uncovered.

In the channel offshore from pier 3 (station 36), a bottom composed of 33 inches of partially degraded sludge mixed with sand supported 1,346 polychaetes per square foot and three kinds of other organisms. The sludge and sand mixture had organic carbon and nitrogen values of 3.5 and 0.24 percent respectively. Offshore from the 28th Street pier, artificial substrates hanging from a buoy in the channel contained over 3,178 organisms per square foot as opposed to 488 per square foot in South Bay. Such conditions are indicative of moderate pollution and may be due to resuspension and deposition of sludge from between piers into the channel as a result of frequent ship movements in the area or to the discharge of wastes from naval ships into the bay. Across the bay and out of the channel (station 54), a core sample contained sand, silt,

and shells with 0.8 percent organic carbon and 0.03 percent organic nitrogen.

Wastes from a kelp processing company are discharged into the bay at a point approximately 250 yards from shore. Near the outfall, where scouring action prevented sludge build-up, 152 polychaetes per square foot and one other organism were able to exist. Low numbers of polychaetes, 27 to 35 per square foot, as well as zero to one kind of organism other than polychaetes (Table 2) were found in areas sampled approximately 100 feet north and 200 feet east of the outfall (stations 27 and 28). The bottom was blanketed with 16 to 34 inches of black sludge covered with a layer of ground kelp, oil and perlite. The sludge contained 4.0 to 7.9 percent organic carbon and 0.59 to 0.96 percent organic nitrogen, typical of actively decaying material. Mixed in the sludge perlite was used as a filter aid in the processing of kelp. The presence of oil may be due to spillage from fuel docks in the area. Discharge of kelp wastes into the water produced a turbid condition that was visible on the water surface for a distance of several hundred yards from the outfall. Such conditions, resulting

from the discharge and heavy deposition of kelp wastes, as well as the presence of oil which can be toxic to benthic organisms, destroyed the habitat and the potential for bottom organism development.

Wastes from a tuna cannery were discharged from several open pipes on the shore. Sludge banks from these wastes extended approximately 200 yards off-shore and downbay to the 10th Avenue terminal. Polychaetes numbering as high as 368 per square foot and one other kind of organism were found near the ends of the piers (station 24). Closer to shore, over 300 polychaetes per square foot along with a few snails and a clam were able to exist. Divers swimming along transects in the area noted a soft, dark, black mud with some flocculent material overlain by a layer of decomposing ooze. Samples of sludge had a distinct hydrogen sulfide odor. Inside the pierhead at the tuna cannery (station 25), 30 inches of sludge contained 5.2 percent organic carbon and 0.4 percent organic nitrogen, typical of actively decomposing sludge. Sampling beyond the piers off-shore from the tuna cannery revealed a light covering of old stable sludge (organic carbon and nitrogen values of 1.3 and 0.27 percent, respectively). Indications are that settleable solids

from the tuna and kelp plant outfalls are deposited close to shore in areas where piers act as baffles to the currents.

From an area near the Tenth Avenue marine terminal (station 23), benthic samples contained 21 polychaetes per square foot. Thirteen inches of decayed sludge mixed with oil covered the bottom. Toxicity of the oil limited both numbers and kinds of organisms and restricted the biological degradation of organic substances, thus allowing an accumulation of sludge.

Samples obtained in Glorietta Bay at station 55 contained only 22 polychaetes per square foot and one other kind of organism (Table 2) indicating moderate to severe pollution. The bottom had a covering of decayed sludge with an organic carbon content of 2.4 percent. This sludge may have originated from the navy landing area or from boats in the yacht harbor. Approximately two hundred yards from the end of Glorietta Bay, a sand bottom supported 462 polychaetes and three kinds of other organisms, typical of areas that are only slightly polluted.

North Bay

The northern section of San Diego Bay had localized areas of pollution. Close to shore in the Carrier Basin, only

polychaetes numbering 190 per square foot were found. Approximately 600 yards from shore, bottom materials had stabilized enough to support 40 polychaetes and 30 molluscs (of one species) per square foot. Over 30 inches of decayed sludge with 2.0 to 2.2 percent organic carbon covered the bottom which was moderately polluted. Before 1963, the sewage outfall for the city of Coronado was located just east of the Basin. Since the Basin is 40(+) feet in depth with little circulation, a sludge build-up resulted. Settleable solids discharged from carriers docked in the Basin would also contribute to the sludge bed. A diver sampling growths on piling near shore reported a visibility of 30 feet which is good when compared with 3 to 4 feet in the vicinity of the naval piers.

At the junction of B Street pier and the shoreline, a storm sewer outfall discharged organic wastes and other debris from the San Diego Zoo into the bay. Samples of the bottom within an approximately 40,000 square foot area surrounding the outfall contained leaves, straw, peanut shells, oil and black sludge that emitted hydrogen sulfide odors (stations 17, 18 and 19). Sulfide conditions are indicative of anaerobic decomposition of organic materials. The area supported 98 to 1178 polychaetes per square foot and pollution-tolerant snails and scuds. Sludge sampled

was five inches deep. A maximum depth of sludge was not ascertained. Samples taken 300 feet northwest of the outfall contained a sludge-clay mixture and no debris. Divers noted 2 to 3 foot high piles of dark black flocculent material under the B Street pier and mounds of debris extending 100 to 150 feet from the pier. All these conditions indicated severe pollution of the area. Samples taken north of this area and near the piers used for docking of tuna boats contained sludge-like materials that supported 48 polychaetes per square foot and only one other kind of organism typical of a moderately polluted habitat.

Inside Harbor Island (station 12), 6426 polychaete worms per square foot were the only organisms found; in contrast to only 86 worms per square foot and seven kinds of organisms in addition to the polychaetes at station 13 (Table 2). Sand had been dredged from the area near station 12 and the remaining bottom material inside Harbor Island had been redistributed. At station 12, a depression in the bottom had collected organic debris from the surrounding sand when it was redistributed, thus providing an organically polluted substrate resulting from dredging.

Many polychaete worms (3,379 per square foot) were found at the entrance to the Commercial Basin. Bottom materials were primarily sand. Halfway between the entrance and the end of the Basin, a population of 2,083 polychaetes per square foot existed in a sand and clay mixture. Three-fourths of the distance into the basin, a soft, black decayed sludge supported 210 polychaetes per square foot and three other kinds of organisms including pollution-tolerant snails and crabs. Suspended organic materials discharged from vessels docked in the area and in water entering the bay settles out of the slow moving water at the end of the Basin. Toward the entrance to the Basin, currents prevented the deposition of large amounts of material on the bottom and a larger number of polychaetes were able to exist in the sludge and sand mixture. The high number of polychaete worms present in the Basin indicates moderate pollution of the area. An unpolluted area would support a larger variety of organisms than the 2 to 4 kinds found in the Basin, and would have lesser number of worms.

A sand and clay substrate supported 290 polychaete worms per square foot and eight other kinds of organisms at station 7 between Shelter Island and the main shipping channel. The

number of polychaetes indicated a slightly polluted environment. Divers noted that the bottom near buoy 7 was swept clean by main channel currents. These currents probably prevent the deposition of materials in the vicinity of Shelter Island.

The bottom of Shelter Island Harbor was covered with a black sludge-like material that supported 803 polychaetes per square foot. Near the harbor entrance, consistency of the bottom materials changed to sand and clay with 936 polychaetes per square foot. The area was lightly to moderately polluted, probably because of wastes discharged from the large number of boats in the harbor and from storm water runoff. Also settleable materials entering the harbor would tend to settle out in the slower moving waters.

From Shelter Island out to the entrance of San Diego Bay, excluding the submarine base which was not sampled, the benthic populations ranged from 42 polychaetes to 141 polychaetes per square foot and 4 or 5 other kinds of organisms. A sand, clay and shell mixture formed a substrate acceptable to a variety of organisms. Divers noted that the most diverse and abundant assemblages of organisms existed in the entrance channel-outer bay area. This area was unpolluted.

SUMMARY

Pollution in San Diego Bay occurred mainly in the Central Bay area. A tuna cannery and kelp-processing plant discharged wastes into the bay waters with a resultant build-up of sludge deposits exceeding 30 inches in depth, and a degradation in the benthic animal community. The animal community was composed only of large numbers of polychaete worms. In the vicinity of naval piers 2 through 8, decomposing sludge was 44 inches in depth and extended from the shoreline to approximately halfway out to the ends of the piers. Here benthic organisms were restricted to low numbers of polychaete worms (2 to 115 per square foot). The remaining area around the naval piers was covered with a layer of sludge capable of undergoing additional decay. In addition to polychaetes, three kinds of organisms only were able to exist in the bottom materials here.

South Bay was polluted in two areas. The San Diego steam electric plant discharged heated water to the bay and produced a polluted condition in the effluent channel area. Offshore from Rohr aircraft, a heavy growth of algae emphasized the discharge of nutrients into the water.

North Bay was polluted near the D Street pier. A sludge bed covered approximately 40,000 square feet. Inside Harbor Island, the Commercial Basin and Shelter Island, the bottom was covered with decayed organic sludge or debris. These areas were highly enriched, but not seriously polluted. The Carrier Basin contained over 30 inches of decayed sludge supporting polychaetes and molluscs which indicated moderate pollution of the area.

Table 1.

San Diego Bay Bottom Organisms

Kinds and Numbers Per Square Foot

October 1967

Organisms	Station Designation															
	S-1	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-17	S-18	S-19
Marine Annelids																
Polychaeta	141	42	56	936	803	290	3379	2083	210	67	6426	86	48	1178	99	98
Flatworms																
Nemertea	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scuds																
Amphipoda																
Gammaridae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Caprellidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sow Bugs																
Isopoda	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Mysidaceans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cumaceans	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ostracods																
Ostracoda				-	-	-	-	-	-	-	-	-	-	-	-	-
Shrimp																
Spirontocaris sp		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Betaeus sp		-	-	-	-	-	-	-	2	-	-	-	2	-	-	-
Mantis Shrimp																
Pseudosquilla sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Molluscs																
Pelecypoda																
Mytilus sp	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Chione sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tellina sp	-	13	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Macoma sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Transennella sp	-	-	5	-	-	5	-	-	-	-	-	-	-	-	-	-
Mytilus sp	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-
Musculus sp	-	-	21	-	-	1	-	-	-	-	-	-	-	-	-	-
Nuculana sp	-	2	-	-	-	5	-	-	-	-	-	14	-	-	-	-
Solen sp	-	-	1	-	-	16	-	-	-	-	-	3	-	-	-	-
Tagelus californianus	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Solen sp	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-
Lyonsia sp	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-
Others	27	3	-	-	3	-	-	-	-	-	-	-	-	-	-	-
Gastropoda																
Crepidula sp	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-
Amphibulum sp	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-
Acteon sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nassarius sp	-	5	3	-	-	-	-	-	-	-	-	5	-	-	-	-
Olivella sp	-	5	-	-	-	-	-	-	5	2	-	-	-	6	-	2
Pachyphynchus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bulla sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Others	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Crabs																
Inachoides sp	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-
Pinnixa sp	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Hemigrapsus sp	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
Lophopanopeus sp	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Brittle Stars																
Ophiurodea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coelenterata																
Anthozoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tunicata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Number of Organisms Per Square Foot	181	70	88	936	808	335	3381	2085	219	69	6426	118	50	1184	103	100
Total Number of Kinds	5	6	6	1	3	9	2	2	4	2	1	8	2	2	3	2

Reproduced from best available copy.

Table 1 Cont.

San Diego Bay Bottom Organisms

Kinds and Numbers Per Square Foot

October 1967

Organisms	Station Designation																
	S-21	S-22	S-23	S-24	S-25	S-26	S-27	S-28	S-29	S-30	S-31	S-33	S-34	S-35	S-36	S-37	S-38
Marine Annelids																	
Polychaeta	62	30	21	368	301	152	27	35	16	30	176	827	13	77	1346	61	115
Flatworms																	
Nemertea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scuds																	
Amphipoda																	
Gammaridae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caprellidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sow Bugs																	
Isopoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Mysidaceans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-
Cumaceans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ostracods																	
Ostracoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shrimp																	
Spirontocaris sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Betaeus sp	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-
Mantis Shrimp																	
Pseudosquilla sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Molluscs																	
Pelecepoda																	
Mytilus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Geukensia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chionista sp	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Diplodonta sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptopecten sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tivela sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Macoma sp	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-
Tagelus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chione sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-
Cyclocardia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solen sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lyonsia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Others	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gastropoda																	
Crepidula sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crucibulum sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Netusa sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Nassarius sp	-	6	-	6	2	-	-	-	-	-	-	2	-	-	-	-	-
Olivella sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tachyrhynchus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bulla sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Others	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crabs																	
Inachoides sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pinnixa sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hemigrapsus sp	-	2	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-
Lophopanopeus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brittle Stars																	
Ophiurodea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coelenterata																	
Anthozoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tunicata	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Total Number of Organisms Per Square Foot	64	38	21	374	307	157	29	35	18	30	176	829	13	77	1356	74	115
Total Number of Kinds	2	3	1	2	4	2	2	1	2	1	1	2	1	1	4	4	1

Table 1 Cont.

San Diego Bay Bottom Organisms

Kinds and Numbers Per Square Foot

October 1967

Organisms	Station Designation																
	S-39	S-40	S-41	S-42	S-43	S-44	S-45	S-46	S-47	S-48	S-49	S-50	S-51	S-52	S-53	S-54	S-55
Marine Annelids																	
Polychaeta	178	13	74	11	19	211	238	309	365	498	118	1408	288	829	190	378	22
Flatworms																	
Nemertea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-
Scuds																	
Amphipoda																	
Gammaridae	-	-	-	-	-	-	-	-	-	29	43	-	2	2	90	8	-
Caprellidae	-	-	-	-	-	-	-	-	-	26	-	-	-	45	10	-	-
Sow Bugs																	
Isopoda	-	-	-	-	-	-	-	-	-	27	-	13	-	-	3	-	-
Mysidaceans	3	-	-	-	-	-	-	-	-	16	-	-	-	26	-	-	-
Cumaceans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ostracods																	
Ostracoda	-	-	-	-	-	-	-	-	3	6	-	-	-	2	32	-	-
Shrimp																	
Spirontocaris sp	-	-	-	-	-	-	2	-	3	-	-	-	-	-	-	-	-
Betaeus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Mantis Shrimp																	
Pseudosquilla sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Molluscs																	
Pelecepoda																	
Mytilus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Geukensia sp	-	-	-	-	-	-	-	-	5	-	-	-	-	-	2	-	-
Chionista sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diplodonta sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptopecten sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tivela sp	-	-	-	-	-	-	-	-	-	14	-	-	-	67	2	-	-
Macoma sp	-	-	-	-	-	-	-	-	-	-	6	-	19	-	-	34	-
Tagelus sp	-	-	-	-	-	-	-	-	2	2	-	-	67	6	-	-	-
Chione sp	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	5	-
Cyclocardia sp	-	-	-	-	-	-	-	2	14	13	-	-	-	-	-	-	-
Solen sp	-	-	-	-	-	-	-	-	5	-	5	-	-	-	-	-	-
Lyonsia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	-	-
Others	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-
Gastropoda																	
Crepidula sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Crucibulum sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	61	5	-
Retusa sp	-	-	-	-	-	-	-	-	-	13	-	-	-	13	-	-	-
Nassarius sp	2	-	-	2	-	-	-	-	-	-	-	-	2	-	-	3	-
Olivella sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yachyrhynchus sp	-	-	-	-	-	-	-	-	-	-	2	307	5	-	-	-	-
Bulla sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Others	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crabs																	
Inachoides sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pinnixa sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hemigrapsus sp	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	-	-
Lophopanopeus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brittle Stars																	
Ophiuroidea	-	-	-	-	-	-	-	-	3	-	-	-	-	-	6	-	-
Coelenterata																	
Anthozoa	-	-	-	-	-	-	-	-	-	18	-	-	-	-	2	-	-
Tunicata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Number of Organisms Per Square Foot	183	13	74	13	19	211	240	311	400	664	180	1728	383	990	434	439	24
Total Number of Kinds	3	1	1	2	1	1	2	2	8	12	8	3	6	8	13	9	2

Table 1 Cont.

San Diego Bay Bottom Organisms

Kinds and Numbers Per Square Foot

October 1967

Organisms	Station Designation S-56	S-57	S-58	S-59
Marine Annelids				
Polychaeta	462	190	40	42
Flatworms				
Nemertea	-	-	-	-
Scuds				
Amphipoda				
Gammaridae	-	-	-	-
Caprellidae	-	-	-	-
Sow Bugs				
Isopoda	-	-	-	-
Mysidaceans	-	-	-	-
Cumaceans	-	-	-	-
Ostracods				
Ostracoda	-	-	-	-
Shrimp				
Spirontocaris sp	-	-	-	-
Betaeus sp	3	-	-	-
Mantis Shrimp				
Pseudosquilla sp	-	-	-	-
Molluscs				
Pelecepoda				
Mytilus sp	-	-	-	-
Geukensia sp	-	-	-	-
Chionista sp	-	-	-	-
Diplodonta sp	-	-	-	-
Leptopecten sp	-	-	-	-
Tivela sp	-	-	-	-
Macoma sp	-	-	-	-
Tagelus sp	-	-	-	-
Chione sp	2	-	29	34
Cyclocardia sp	-	-	-	-
Solen sp	-	-	-	-
Lyonsia sp	-	-	-	-
Others	-	-	-	-
Gastropoda				
Crepidula sp	-	-	-	-
Crucibulum sp	-	-	-	-
Retusa sp	-	-	-	-
Nassarius sp	4	-	-	-
Olivella sp	-	-	-	-
Tachyrhynchus sp	-	-	-	-
Bulla sp	-	-	-	-
Others	-	-	-	-
Crabs				
Inachoides sp	-	-	-	-
Pinnixa sp	-	-	-	-
Hemigrapsus sp	-	-	-	-
Lophopanopeus sp	-	-	-	-
Brittle Stars				
Ophiuroidea	-	-	-	-
Coelenterata				
Anthozoa	-	-	-	-
Tunicata	-	-	-	-
Total Number of Organisms Per Square Foot	471	190	69	76
Total Number of Kinds	4	1	2	2

Table 2. Total Number and Kinds of Benthic Organisms at Selected Sampling Stations in San Diego Bay, October 1967

Station No.	Total Number of Organisms/ft^2	No. of Kinds	Total No. of Polychaete/ft^2
1	181	5	141
3	70	6	42
4	88	6	56
5	936	1	936
6	808	2	803
7	335	9	290
8	3381	2	3379
9	2086	2	2083
10	219	4	210
11	69	2	67
12	6426	1	6426
13	118	8	86
14	50	2	48
17	1184	2	1178
18	103	3	99
19	100	2	98
21	64	2	62
22	38	3	30
23	21	1	21
24	374	2	368
25	307	4	301
26	157	2	152
27	29	2	27
28	35	1	35
29	18	2	16

Table 2 Cont.

Station No.	Total Number of Organisms/ft^2	No. of Kinds	Total No. of Polychaete/ft^2
30	30	1	30
31	176	1	176
33	829	2	827
34	13	1	13
35	77	1	77
36	1356	4	1346
37	74	4	61
38	115	1	115
39	183	3	173
40	13	1	13
41	74	1	74
42	13	2	11
43	19	1	19
44	211	1	211
45	240	2	238
46	311	2	309
47	400	8	365
48	664	12	498
49	180	8	118
50	1728	3	1408
51	383	6	288
52	990	8	829
53	434	13	190
54	439	9	378
55	24	2	22
56	471	4	462
57	190	1	190
58	69	2	40
59	76	2	42

Table 3. Percent Organic Carbon and Organic Nitrogen in Sludge Deposits and Total Sludge Depth at Selected Stations in San Diego Bay, October 1967

Station Number	Percent Organic Carbon*	Percent Organic Nitrogen*	Total Sludge Depth in Inches	Remarks
2	0.4	0.10	0	Sand
6	1.3	0.18	29.0	
8	1.1	0.08	0	Sand and Silt
10	1.7	0.10	20.0	
13	2.2	0.11	0	Sand
23	1.9	0.12	13.0	
24	1.8	0.27	0	Sand and Clay
25	6.2	0.46	30.0	
26	4.0	0.70	16.0	
27	6.3	0.59	34	
28	7.9	0.96	**	Dredge Sample
31	3.0	0.19	34	
32	3.9	0.19	14	
33	4.5	0.33	14	
34	2.5	0.17	30	0-11 inch layer
	5.2	0.33		12-30 inch layer
35	3.8	0.27	26	0-8 inch layer
	8.5	0.56		9-21 inch layer
	3.4	0.17		22-26 inch layer
36	3.3	0.24	33.0	
37	2.0	0.18	32	0-12 inch layer
	6.1	0.44		13-32 inch layer
38	3.3	0.32	44	0-17 inch layer
	2.6	0.21		18-23 inch layer
	1.8	0.19		24-44 inch layer

Table 3 Cont.

Station Number	Percent Organic Carbon*	Percent Organic Nitrogen*	Total Sludge Depth in Inches	Remarks
42	2.2	0.14	33.0	
43	5.6	0.38	33.0	
45	4.1	0.36	2.0	
49	1.6	0.16	33.0	Mud and Sand
50	2.3	0.16	25.0	
54	0.8	0.03	0	Sand and detritus
55	2.4	0.20	**	Dredge Sample
56	0.8	0.08	0	Sand and detritus
57	2.0	0.14	35.0	
59	2.2	0.17	31.0	

*Values reported are for the 0-1 inch layer; exceptions noted in remarks.

**Undetermined